ZDM Mathematics Education (2016) 48:227–238
DOI 10.1007/s11858-016-0771-2

COMMENTARY PAPER

Teacher noticing: enlightening or blinding?

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Accepted: 25 February 2016 / Published online: 2 March 2016

Abstract This paper comments on the theoretical formulations and usage of the construct of teacher noticing in a selection of the papers in this special issue of ZDM Mathematics Education. The analysis of how the notion of teacher noticing is used in the papers suggests that it draws attention to several interdependencies involved that have not been attended to in the past. However, the contributions in this special issue have only partially accounted for the dynamic interactions in teacher noticing, suggesting that there is potential for enriching our understanding of the complexities involved in the realm of teacher noticing. The purpose of this commentary is to stimulate the current discussion on teacher noticing by providing insights from cognitive science and the applied science of human factors, which have the potential to challenge the current understanding of noticing. In doing so, the paper sets the stage for several related constructs from these research disciplines to raise awareness of aspects that recent conceptualizations of teacher noticing may have blinded rather than enlightened.

Keywords Attention · Perceptual cycle model · Situation awareness · Teacher cognition · Teacher noticing · Theory development

1 Introduction

Theoretical constructs are valued for their potential in advancing knowledge in a scientific discipline, in guiding research toward crucial questions, and in enlightening aspects that we otherwise had not seen or conceived.

> Constructs are not valued simply in terms of whether they are right or wrong; instead, they are valued by their usefulness to the field. Occasionally a construct emerges that transforms the field by enabling researchers to reconceptualize their endeavors and to shift, sometimes in subtle ways, the focus of their attention. (Sherin, Jacobs, & Philipp, 2011a, p. 3)

This potential has been attributed to the construct of *teacher noticing* by Sherin et al. (2011a); a construct that seems to cross the threshold of the mainstream of teacher research. Despite the relatively short time since teacher noticing has entered the vernacular of researchers and practitioners in mathematics education, there is actually quite a collection of contributions on the notion of teacher noticing (Jacobs, Lamb, & Philipp, 2010; Kaiser, Busse, Hoth, König, & Blömeke, 2015; König et al., 2014; Sherin, Jacobs, & Philipp, 2011b; Star & Strickland, 2008).

The papers in this special issue, taken together, offer a collection of important advancements of teacher noticing, and provide insight by presenting original approaches in integrating various research lines into the frame of noticing that may constitute a more advanced understanding of the observed phenomena. However, several papers seem to be guided by intuitive frames, speaking about teacher noticing as though its meaning were self-evident, or even treating teacher noticing as an explanatory construct for certain phenomena. As scientists, we cannot afford to be seduced by simple, intuitive, easy-to-understand answers. Instead we need to recognize that there may be more to this situation than meets our eyes. We need to recognize that teacher noticing is not an answer but a real and important question that invites us to enlighten (rather than blind) critical

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aspects in the field of teacher competence. This is exactly what is set as the goal for this commentary. In this paper, it is argued that there is room for further contributions in the process of indicating where to direct our eyes to—an opportunity for our field to question interactions and interdependencies in the realm of teacher noticing that we thought we understood.

This commentary examines the general contribution of various papers in this special issue. Yet, the very notion of selective looking (see Neisser, 1976) reminds us that we, as researchers, conduct research using a particular lens and that this focus has a bearing on what is noticed, that is, what is perceived and attended to, interpreted as significant, and ultimately reported. This use applies to commentators as well. The focus of this commentary will be on the usage of the construct of teacher noticing, and the postulated value of it in enlightening issues that otherwise have not been acknowledged. Then, some directions for future research will be developed by drawing on notions originating in cognitive science and the applied science of human factors that may allow us to see with greater perspective the complexities involved in the realm of teacher noticing.

This commentary aims at an interpretation and blending of several ideas gained from the various contributions to this issue with the goal of seeing profoundly and unconventionally into phenomena that are necessary to understand.

2 Teacher noticing: a critical and evolving theoretical construct

The merits of any body of research may be judged by how well it contributes to a current discussion and how well it represents an incremental advance in our understanding. Many papers in this special issue of ZDM Mathematics Education have certainly done so: they moved scholars in the field and advanced our understanding of many critical issues. Another way to judge the value of research is how well it contributes to seeing issues we thought we understood in a different way, how well it offers a critical redirection of existing views or provides a surprising advance in understanding, or even violates our intuition. The body of research considered in this paper has been evaluated based on these criteria. In this section, several contributions to this special issue that progressively advanced our field are highlighted. However, a more critical stance is also adopted in commenting on aspects that have been only partially considered and occasionally oversimplified.

The approach taken here will be more than usually assertional in the hope of raising issues provocatively. As the issues are deep and complex and simply cannot be elaborated in any great detail, they will mostly be defined rather than uncovered, explicated or settled.

In the following subsections, first a global focus is adopted on the ways in which contributions in this special issue enriched the emergent picture of teacher competence. Then the lens is focused on specific issues in the research on teacher noticing: what explicit and implicit assertions are made with regard to the various activities involved, their relation to each other, and how data has been analyzed.

2.1 Emerging insights in and new targets for research on teacher competence

Blömeke, Gustafsson, and Shavelson (2015) observed that, in the past, research on teacher competence focused primarily either on teacher dispositions in terms of cognition, affect, and motivation-volition or on teacher performance. In an attempt to overcome the ongoing tension in separating research on teacher dispositions from research on teacher performance, Blömeke et al. (2015) enunciated an integrated perspective articulating competence as a *continuum* of dispositions and performance. Blömeke et al. (2015) proposed to consider competence as "a continuum from traits (cognitive, affective, motivational) that underlie […] perception, interpretation, and decision making that give rise to observed behavior in a particular real-world situation" (p. 11). In this light, situation-specific skills including perception, interpretation, and decision-making were considered as mediating the transformation of dispositions into practice.

Dunekacke, Jenßen, Eilerts, and Blömeke (2016, this issue) supported this viewpoint on competence, arguing, based on their empirical findings, that special parts of knowledge and beliefs could predict preservice preschool teachers' perception and planning skills. Interestingly, when knowledge and beliefs have both been controlled, mathematical pedagogical content knowledge and application-related beliefs could predict the perception skills of prospective preschool teachers. Prospective preschool teachers' perception skills could then be used to predict their planning skills, while mathematical content knowledge was modeled as a precondition for mathematical pedagogical content knowledge.

On the other hand, Herbst, Chazan, Kosko, Dimmel, and Erickson (2016, this issue) made a case against a reductionist view of human action as only individual agency. They argued for going beyond the dominating account of the influence that individual cognitive factors have in decision-making by considering not only individual resources but also contextual resources. Herbst et al. (2016, this issue) hypothesized that decisions teachers make are "products of how individuals use personal resources to negotiate the demands of their institutional positions and the norms of the activities in which they play roles". They particularly paid attention to instructional

norms and professional obligations as two sets of contextual resources that might help account for teachers' decision making. Similarly to the perspective proposed by Herbst et al. (2016, this issue), Lande and Mesa (2016, this issue) argued that not taking into account the working environment and other socio-cultural influences in understanding teacher action would be problematic. They argued that the societal and institutional contexts shape the role of teachers by establishing norms of professional behavior when individuals enact those roles and by defining obligations to which teachers respond. Lande and Mesa (2016, this issue) took a more ecological stance for understanding the work of mathematics teaching by recognizing that mathematics teaching is situated within classrooms (working environment), institutions (institutional environment), as well as social environments (society). In doing so, Herbst et al. (2016, this issue) and Lande and Mesa (2016, this issue) broadened the discussion on teacher competence by attending to both the psychological and socio-cultural influence and the interaction between them that may inform teachers' decision making.

To account for the influence of teacher communities on teachers' instructional decision making, Santagata and Yeh (2016, this issue) explicitly included communities in their conceptualization of teacher competence. These authors identified that the context in which teachers worked and other professional communities in which they engaged also served as lenses for attending to and interpreting their practices, and for making decisions. In their analysis consisting of a classroom video analysis survey, videotaped lessons, and post-lesson interviews, Santagata and Yeh (2016, this issue) came to a different conclusion than the view of competence Blömeke et al. (2015) suggested. Santagata and Yeh argued that perception, interpretation, and decision-making are at the center of the overlap of knowledge and beliefs with classroom practice. These situation-specific skills function as the processes through which knowledge and beliefs become relevant in practice. Conversely, the process of deliberately attending to, interpreting, and making decisions based on practice creates new knowledge and new beliefs, thus enabling changes in competence. Practice therefore functions as a means of refining perception, interpretation, and decision-making and of increasing knowledge and changing beliefs. This bi-directional relationship between knowledge, beliefs, skills, and practice differs from Blömeke et al.'s (2015) more linear, unidirectional conceptualization of competence. While Blömeke et al. (2015) proposed to consider competence as a continuum from dispositions to performance, Santagata and Yeh (2016, this issue) suggested considering teacher competence as a complex interaction of situated knowledge, beliefs, and practices that can be understood only in the specific context in which teachers work.

Overall, the merit of Santagata and Yeh's (2016, this issue) approach is the acknowledgement of the interdependence between an individual and the environment—an interdependence that surprisingly often remained unnoticed. Interactions between individual and contextual resources, situation-specific skills (such as perceiving, interpreting, and decision-making), and the environment have never been fully described in contemporary research, and often remain in the 'black box'.

2.2 Determining and defining activities in teacher noticing

The notion of teacher noticing has many faces, as previous contributions and the various contributions in this special issue revealed. Philipp, Jacobs, and Sherin (2014) asserted a range of conceptualizations of noticing in mathematics education. The same holds for many papers in this special issue. Descriptions of teacher noticing used in a selection of these papers are considered, such as Hoth et al. (2016, this issue), who used Kaiser et al.'s (2015) so-called PID-model comprising (a) *perceiving* particular events in an instructional setting, (b) *interpreting* the perceived activities in the classroom, and (c) *decision-making*, either as anticipating a response to students' activities or as proposing alternative instructional strategies, which is closely connected to the approach by Blömeke et al. (2015). Santagata and Yeh (2016, this issue) focused on (a) *attending* to the mathematics content at the center of the instruction, (2) *elaborating* on students' mathematical thinking and learning, and (c) *proposing improvements* in the form of alternative strategies teachers might adopt to enhance students' learning opportunities. These conceptualizations announce a variety of key activities: perceiving, attending, interpreting, elaborating, proposing improvements, and decision-making. These conceptualizations paint a picture fairly consistent with earlier approaches specifying activities involved in teacher noticing. For instance, Jacobs et al. (2010) conceptualized professional noticing of children's mathematical thinking as comprised of three skills: (a) *attending* to children's strategies, (b) *interpreting* children's understandings, and (c) *deciding how to respond* on the basis of children's understanding.

These contributions bring to the surface several critical activities (such as attending, interpreting, and decision-making) that allow the world to be seen in new and different terms. Although most authors tried to be quite specific in determining what the important elements of teacher noticing are, there is still room for making more precise the meaning of the terms used, clarifying how they are related to or differ from the ones used by other scholars, as well as for clarifying the appropriateness of their terms. The terms used in conceptualizing teacher noticing seem to bring into

discussion much of the vocabulary of cognitive psychology, but apparently often based on intuitive, not necessarily appropriate, understanding. Almost all the effort in pursuing the meanings of terms, their integrity and general utility is left to the theoretically reflective reader. Section 3 provides a point of departure in thinking about the concern of perceiving and attending.

2.3 Relating activities involved in teacher noticing: continual, sequential, or interactional?

Currently researchers agree that teacher noticing is seen as a set of various activities, skills, or processes; however, they differ not only in the terms used but also in their assumptions of how these activities might be related to one another. Several scholars made explicit or implicit assertions concerning the relation between the various activities attributed to the construct of teacher noticing. Although these assertions were not the focus of their papers, they are important as they highlight a diversity of views about relationships which otherwise may be thought of as self-evident.

For instance, Bruckmaier, Krauss, Blum, and Leiss (2016, this issue) specified that "although the teachers investigated in the COACTIV video-study obviously had to perceive and interpret the video stimuli […], only the resulting *final continuation* ("decision") was assessed". The term 'final continuation' causes some kind of confusion. It raises the question of how something can be 'final' when it 'continues'. Is perceiving considered as one pole of a spectrum, and decision making as the other pole? In any case, this formulation carries the connotation that activities are ordered. One might think that the authors think in terms of a linear order or hierarchical order, or even that the various activities are embedded in one another. The point is that Bruckmaier et al.'s (2016, this issue) assertion allows much room for speculation. Santagata and Yeh (2016, this issue), on the other hand, hypothesized a "*cyclical process* of perception, interpretation, and decision making". The difference between a linear (or hierarchical) process and a cyclical process is that the latter implies an on-going process. Pankow et al. (2016, this issue) referred the identification of typical students' errors "to the first *phase* of noticing, namely the perception and anticipation of important classroom incidents". In doing so, they explicated that, in their opinion, noticing consists of several ordered phases, the first being the anticipation and perception. Similarly, Hoth et al. (2016, this issue) mentioned with regard to the PID-model that perception, interpretation, and decision-making are *phases*, whereas Dunekacke et al. (2016, this issue) hypothesized perception, interpretation, and planning action as being *steps*. One might think, based on these statements, that these activities take place sequentially or successively.

The diverse views presented in this special issue show that the relationship between the various activities is non-obvious. Interestingly, almost all mentioned papers treated the issue as given, considering the various activities as phases or steps in a continuum or in a cycle, among others. Yet reasonable clarity regarding how the activities are related to one another is still missing. Dyer and Sherin (2016, this issue) take a different stance, explicating that they do not mean to suggest that a teacher first develops an interpretation of student thinking and then reasons about it. Instead they propose a more dynamic relationship between the two processes. Their model of the way teachers make sense of student thinking treated interpretations and instructional reasoning as working in conjunction with one another, and could be iteratively revised and used flexibly. Similarly, Sherin et al. (2011a) suggested considering 'attending' and 'making sense' as "interrelated and cyclical" (p. 5). Based on empirical grounds, Dunekacke et al. (2016, this issue) stated a strong relation between perception and planning, indicating that the two activities cannot be distinguished empirically; however, despite their empirical finding, the authors suggested distinguishing between the two 'categories'—both in theory and in practice. This, obviously, raises more questions than it provides answers.

The argument is that more often neither theoretical nor empirical contributions justified the deduction and confirmation of the postulated relationship of the activities involved in teacher noticing. However, we need to be cautious about deducing the relational nature of the activities in order to avoid the risk of blinding the complexities involved. Section 5 provides the target to problematize the complexities involved more profoundly.

2.4 Theoretical and methodological issues in research on teacher noticing

Discussions of teacher noticing in this special issue have acknowledged the importance of theoretical frames in bounding problems of consideration. Bounding allows us to identify, from the many potential dimensions and interactions among dimensions that could be identified with a phenomenon, those aspects to which researchers should attend. Theoretical frames tell which details are relevant.

In many papers of this special issue, the theoretical frame of teacher noticing has been taken as a tool for analyzing the data that often took the form of teachers' comments (or responses) on classroom events: viewing video vignettes of classroom events (Bruckmaier et al., 2016, this issue; Dunekacke et al., 2016, this issue; Hoth et al., 2016, this issue) or drawing on teachers' own teaching in classrooms (Dyer & Sherin, 2016, this issue; Jacobs & Empson, 2016, this issue; Santagata & Yeh, 2016, this issue). To analyze the data, researchers often coded these

comments, placing them either into categories (Bruckmaier et al., 2016, this issue; Kersting et al., 2016, this issue) or identifying new categories (Jacobs & Empson, 2016, this issue; Hoth et al., 2016, this issue). Sherin and Star (2011) reminded us that

> When we say that teachers are 'attending to pedagogy' in their comments, we are saying only what their comments are *about*, from a researcher's point of view, not what they were perceiving. […] These meters [coherent or topic meters] tell us something about emergent features of teacher reasoning. But they do not, in any direct way, tell us anything about the underlying noticing machinery that produced those emergent features. (p. 76, italics in original)

Kersting et al. (2016, this issue) concluded their contribution with the observation that a fundamental challenge is that our theoretical advances are limited by our measures and our measures are limited by our theoretical understanding. Thus, it is not surprising that we have focused our attention on the seemingly most observable aspects in teacher noticing, and that numerical scales have become the dominating measure in teacher noticing. However, quantitative instruments that symbolize teacher' noticing with a number on a scale provide a general orientation for, but fall short of, explaining phenomena of modest complexity. Inherent in a number system is an implication of a unidimensional continuum on which values (points) differ in degree rather than in kind. The use of an overall score for various dimensions or activities involved in teacher noticing (Bruckmaier et al., 2016, this issue; Santaga & Yeh, 2016, this issue), while a useful starting point, does not fully represent the phenomena being studied. As a measure of the extent to which teachers demonstrate the abilities defined by each rubric, the use of an overall score is justified. However, such a measure does not capture the interactions of activities and possible relationships between the dimensions being explored, thus omitting some qualitative detail.

The utility of Kersting et al.'s (2016, this issue) speculation that summating individual scores teachers obtained in various categories allows an interpretation in terms of a knowledge system perspective is unlikely. A knowledge system perspective is of value to provide insights in a structural description of teacher knowledge that accounts for the interactions of knowledge elements, the complex nature of the organization of the knowledge system, the dynamic and fluid nature of knowledge activation, and its non-linear development, amongst others (Scheiner, 2015). An overall score as a measure for the complexity and dynamics of a knowledge system is of limited value.

3 Looking at the black box: on vision and blindness

In the field of teacher noticing, we are guided by, or trapped in, intuitive frames that run the risk of blinding critical issues. As mentioned in Sect. 2.2, this becomes obvious with respect to perceiving and attending: Santagata and Yeh (2016, this issue), for instance, explicated that they used the terms attending and perceiving interchangeably. This may be grounded in the assumption that what we perceive we do attend to, and what we attend to we do perceive. Conversely, several scholars in cognitive psychology and cognitive science have clarified that not all perceived stimuli are attended, and not all attended stimuli are perceived (see Baars, 1997; Lamme, 2003). To illustrate this issue, in drawing reference to Lamme (2003), it is argued that we have various levels of processing that a stimulus can reach: unperceived or perceived, unattended or attended, and implicitly attended (without awareness) and explicitly attended (with awareness).

However, it is found that only in perceived stimuli that are attended and have the potential to be explicitly attended is there evidence of awareness (see Fig. 1). With this in mind, attention selects certain stimuli of a perceived scene for detailed analysis, while perception goes to build up a certain visual experience. Neisser (1976) clarified: "[o]nly the attended episode is involved in the cycle of anticipations, explorations, and information pick up" (p. 87), that is the way of gaining access to awareness. Thus, it is reasonable that Most, Scholl, Clifford, and Simons (2005) stated that "[p]erception is impoverished without attention" (p. 218). The central claim here is that attention is to be considered as selecting stimuli perceived in a scene but also as creating access to awareness. This is important as I believe that ultimately, awareness of the situation is all that matters in a teaching–learning situation. Simons (2000) argued that

> In most real-world settings, the critical question of interest is not whether an object will implicitly affect performance, but whether it will explicitly capture attention and reach awareness, thereby allowing us to modify our behavior and select new goals. Although, much, if not most, of perception and performance occurs without awareness, we feel that when salient events occur, we should become aware of them so that we can intentionally change our behavior. (p. 150)

Recent research on teacher noticing (including the many papers in this special issue) productively investigated *what* a teacher did or did not 'see', and whether a certain event affected a teacher's behavior; however, research is needed

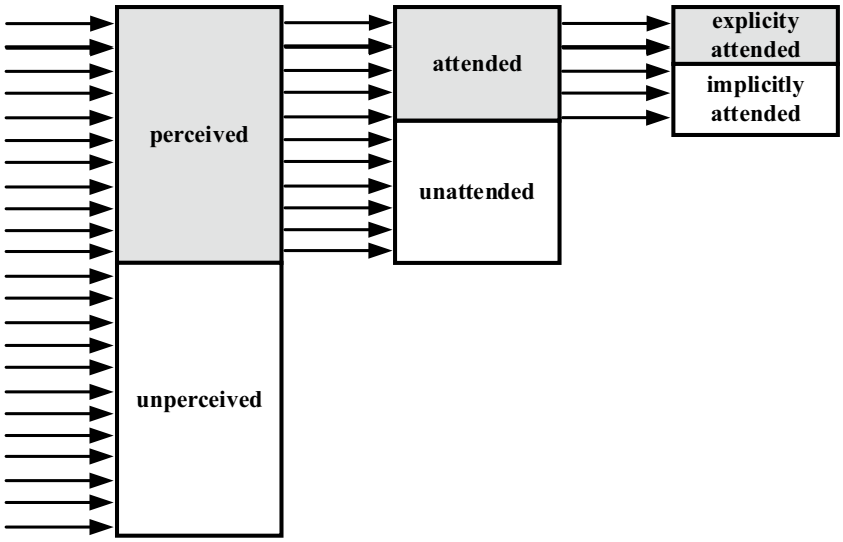

Fig. 1 Perceiving-attending-explicitly attending as the gateway to awareness (modified from Lamme, 2003, p. 13)

in determining the question of *why* a teacher did or did not 'see' a particular event.

At a time when it seems we are guided by, or trapped in, intuitive frames that are of limited explanatory power, we may turn to other research lines from cognitive science such as attention capture and inattentional blindness that may bring to light yet unaddressed issues in the teacher noticing literature: (a) how and why teachers tune into particular events and, at the same time, may remain sensitive to other important events; and (b) how and why different types of attention shifts do or do not give rise to awareness.

3.1 Setting the stage for attention capture and inattentional blindness

Research on attention capture showed that events that have been found to capture attention implicitly might not also capture awareness. Simons (2000), therefore, distinguished between instances in which events affect performance without necessarily impinging on awareness (*implicit attention capture*) from instances in which there is evidence of awareness (*explicit attention capture*). Recent studies of explicit attention capture reveal a surprising degree of blindness to unusual events that might be expected to capture attention. This blindness, known as *inattentional blindness* (Mack & Rock, 1998), is a phenomenon in which individuals fail to notice unexpected events appearing in front of their eyes when their attention is otherwise engaged. Inattentional blindness is particularly striking since it violates our intuition that people should see whatever they direct their eyes to (Mack & Rock, 1998). Several inattentional blindness experiments (see Most et al., 2005; Simons & Chabris, 1999) indicated that, although being engaged in a certain situation, a person may not necessarily explicitly attend to critical elements taking place in the situation. This phenomenon of inattentional blindness has been explained by Neisser (1976): that a person's own *expectations* (or anticipatory schemas) of what belongs in a scene determine where and how attention is directed.

In the following a way is described in which the discussion on teacher noticing may be productively extended, which accounts for a crucial, yet often unaddressed, issue: the teacher's awareness of the situation in which she or he is engaged. In doing so, the notion of situation awareness will be presented, a concept particularly important in the applied science of human factors.

4 Opening the black box: on attention and awareness

Implicit attention capture research and inattentional blindness research have illuminated different processes relevant to the noticing of critical objects. Important insights about the mechanisms of attention shifting can be drawn from the study of implicit attention capture that has focused primarily on measuring effects of certain events on task performance; however, it is still of limited practical value for research on teacher noticing since it primarily explored how well observers can ignore something they expect but know to be irrelevant. Ordinarily, the density of critical events taking place in the classroom raises a different question: how likely are teachers to notice something potentially relevant that they do not expect? Inattentional blindness research has been exploring this question, providing reviewed evidence that, quite often, unexpected events fail to capture attention. However, the literature on inattentional blindness has yielded only limited insights into the factors that determine whether an unexpected event in a dynamic scene captures awareness. This naturally raises the question

of what accounts for developing and maintaining awareness of relevant events in a complex and dynamic situation like the classroom setting.

Most et al. (2005) recognized that the distinction between implicit and explicit attention capture reflects a "fundamental paradox concerning the nature of attention" (p. 218):

> On one hand, people engaging in challenging tasks must often maintain focus, effectively ignoring irrelevant information that might distract them from their goal. […] On the other hand, attention must be distractible; if potentially dangerous or behaviorally relevant objects appear, they should divert cognitive resources. […] A complete explication of attention must incorporate both these seemingly conflicting requirements (Allport, 1989). (Most et al., 2005, p. 218)

The same authors suggested theoretically bridging these two research fields by illuminating mechanisms of awareness and by "shifting the emphasis of the field from demonstrations of perceptual failure to investigations of factors underlying successful noticing" (Most et al., 2005, p. 237). This theoretical bridging of attention capture and inattentional blindness may be achieved by drawing on Neisser's (1976) perceptual cycle model that is discussed in Sect. 5. In accounting for the relation between attention and awareness, the stage will be set for the construct of situation awareness, a notion presented by scholars in the applied science of human factors that is highly relevant for the construct of teacher noticing.

4.1 Setting the stage for situation awareness

Situation awareness is the term used within the applied science of human factors to describe the level of awareness that a person has of the situation she or he is engaged in. Over the past two decades, the construct has become a fundamental theme within the human factors research community and has received considerable attention across a broad range of contexts, including aviation, air traffic, power plant operations, emergency services, and aircraft piloting, from whence the term originated. These contexts share many characteristics including "dynamism, complexity, high information load, variable workload, and risk" (Gaba, Howard, & Small, 1995, p. 20).

The human factors community has not settled on a single definition, or description, of situation awareness, but the most acknowledged one was given by Endsley (1995):

> Situation awareness is the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future. (p. 36)

Inherent in this description are three processes: First, it involves *perceiving* "the status, attributes, and dynamics of relevant elements in the [surrounding] environment" (Endsley, 1995, p. 36). This echoes scholars' understanding, working in the field of teacher noticing, arguing that a teacher must first be able to gather perceptual information from the environment, and, then, be able to selectively attend to those elements that are most relevant to the task at hand. Similarly to teacher noticing, situation awareness as a construct goes beyond mere perception. It also encompasses *comprehending* the current situation, which allows an individual to interpret its relevance in relation to the individual's task and goals. At first glance, one might argue that scholars working in the field of teacher noticing have stressed this issue in the same, or a similar, way. Of course, it echoes the main activity of "making sense of events […] [that is] teachers necessarily interpret what they see, relating observed events to abstract categories and characterizing what they see in terms of familiar instructional episodes" (Sherin et al., 2011a, p. 5). However, comprehending means not only to "form a holistic picture of the environment" but also to determine the "significance of […] elements in light of the pertinent operator goals" (Endsley, 1995, p. 37). This aspect places situation awareness squarely in the realm of ecological realism (Gibson, 1986). Situation awareness also includes the ability to *project* from current events and dynamics to forecast future situation events (and their implications). This ability to predict future events allows for timely decision-making and therefore seems to be of particular importance given the dynamic nature of the situations in which teachers are engaged. It is this aspect that sets situation awareness apart from teacher noticing. One might observe that the construct of situation awareness is similar to teacher noticing but uses different terms; however, a small shift in orientation might make a big difference in the contribution of our research to addressing important issues. For instance, Endsley's (1995) account of "within a volume of time and space" (p. 36) contained in the description of situation awareness points to a critical, yet often only implicitly assumed, aspect in the discussion on teacher noticing: the fact that the state of awareness of some environment is bounded in time and space. As environments change over time, the dynamic nature of situations (e.g., the ever-changing classroom situation) dictates that the person's situation awareness must be constantly maintained and kept up-to-date. Conversely, since people interact with the environment, a person constrains parts of the situation that are of interest to her or him. Thus, time and space become critical concerns in an individual's situation awareness. Attempts to define the essential components of teacher noticing in general suffer from the fact that, given the dynamic environment in which teachers are engaged, the relevance of events depends on

the context, and will vary from time to time. Any conceptualization of teacher noticing needs to account for the relevance of a given event with regard to the context and time it is bounded by.

It is important to explicate that situation awareness is viewed here as theoretically distinct from decision-making, rather than as a single combined construct as many scholars in this special issue suggested with regard to teacher noticing. The argument made is that this distinction is important and real both in terms of models of human information processing and characterizations of dynamic systems (Endsley, 2000). Poor decisions may be made despite a high level of situation awareness for a variety of reasons, such as limited decision choices, lack of experience in similar situations, or unsuitable strategies guiding the decision-making process. Similarly, good decisions may occur despite low or absent situation awareness, particularly if decisions are affected by automaticity of cognitive processes. However, this distinction is not meant to dispute the significance of situation awareness in the decision-making process or the essential link between situation awareness and decision-making in many instances. On the contrary, in highly complex and dynamic environments, situation awareness and decision-making are necessarily highly interactive: decision making is often shaped by situation awareness and situation awareness is often shaped by decision making.

5 Looking inside the black box: on interdependencies between individual and environment

The complex interactions of cognitive and perceptual processes and activities in dynamic situations (such as classrooms) have never been fully described in research on teacher noticing, leaving many aspects of their interdependencies in the 'black box', unseen by researchers and educators and often understood only in isolation. This section intends to provide a first step towards a more comprehensive understanding of the interactions involved. As mentioned above, a more comprehensive stance for understanding attention and awareness may be achieved by blending various insights from cognitive science (attention capture and inattentional blindness) and the science of human factors (situation awareness). In framing this blending, the formulation is drawn on Neisser's (1976) perceptual cycle model that accounts for the interaction between an individual and an environment. Interestingly, other scholars have already been taking advantage of Neisser's (1976) perceptual cycle model in relating research on attention and awareness. In cognitive science, Most et al. (2005) utilized Neisser's perceptual cycle in theoretically bridging attention capture research and inattention blindness research. In the applied science of human factors, Adams, Tenney, and Pew (1995) and Smith and Hancock (1995) brought Neisser's model into the discussion on situation awareness.

5.1 Setting the stage for Neisser's (1976) perceptual cycle model

Neisser (1976) proposed an information-processing model that accounts for the interaction between a person's internal schemas (or mental models), the perceptual exploration, and the situation in which the individual is engaged. Neisser (1976) explicated that "[p]erception and cognition are usually not just operations in the head, but transactions with the world. These transactions do not merely inform the perceiver, they also transform him [or her]" (p. 11, italics in original). The model differs from linear models of information processing by acknowledging a reciprocal and cyclical relationship between a person and an environment. To concretize this position, Neisser's perceptual cycle model (see Fig. 2) suggests that perception is influenced and directed by a person's existing knowledge. This means existing knowledge (in the form of mental models or schemas) may lead to expectations or anticipations of certain events that in turn serve as the vehicle for perceptual exploration. As such, a person samples or picks up information available in the environment that may serve to modify and update schemas, and in turn shifts her or his attention to other critical elements in the environment. This cycle of attention guidance continuously enriches the emerging representation of the situation.

The perceptual cycle model may provide the key to unlock the black box of the complex interactions involved in developing and maintaining situation awareness. As such, the perceptual cycle model offers a promising theoretical perspective

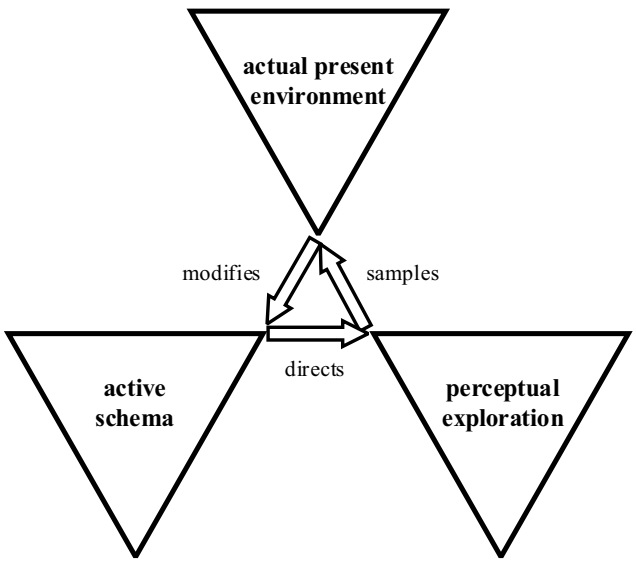

Fig. 2 Perceptual cycle model (adapted from Neisser, 1976, p. 21)

to account for the interdependencies between an individual and an environment in the process of situation awareness. It is a central thesis of this paper that the interactive nature of the perceptual cycle model is persuasive in explaining the dynamic aspects in developing situation awareness. We may argue that, according to the perceptual cycle model, situation awareness emerges through temporally recurrent and active engagement with the environment. Certain elements of the environment do not leap into awareness on initial attention engagement. Rather, the reciprocal and cyclical process proposed by Neisser (1976) is crucial in developing and maintaining an awareness of the actual situation.

It should be explicated that in drawing on Neisser's perceptual cycle model, perception, comprehension, and projection are neither considered as being cyclically related with each other nor as particular phases of the cycle as some scholars in this special issue assumed with regard to activities involved in teacher noticing (see Sect. 2.3). It is unlikely that a teacher sequentially perceives all elements of a situation, then interprets and understands their relevance in relation to her or his task and goals, and then predicts future situation events. In contrast, in naturalistic settings, it is more likely that perceiving, comprehending, and projecting take place concurrently (rather than successively) and are interwoven (rather than separated), and each of these processes apply to the entire cycle. Still, the question of how perception, comprehension, and projection interact remains unanswered. To draw this issue back to teacher noticing, 'attending' and 'making sense' (Sherin et al., 2011a) are, from this point of view, not to be considered as separated but rather interwoven and do not take place successively but concurrently. As Towers and Davis (2002) once indicated: "what we notice is completely framed by what we know. Perception and conception are inextricable. An event of noticing is always and already an event of interpretation" (p. 318).

6 Discussion

Research on teacher cognition and teacher decision-making has mainly focused on constraints internal to the human mind. A real value of the theoretical construct of teacher noticing is to draw attention to the inseparability of individual and environment when addressing issues such as perceiving, interpreting, and decision-making, amongst others. Gibson (1986) referred to this as the challenge of ecological validity. Teacher noticing as a theoretical framing calls attention to a lesson that Gibson (1986) tried to teach long ago: the correspondence between perception and action, and the demands of the environment.

The growing interest in teacher noticing illustrates that scholars in the field of teacher research in mathematics education are coming to recognize the dynamic interactions between teachers' cognitive and contextual resources, teachers' noticing, and teachers' classroom practice. The growing appreciation for these interactions can be seen in several papers in this special issue (Dyer & Sherin, 2016, this issue; Herbst et al., 2016, this issue; Jacobs & Empson, 2016, this issue; Lande & Mesa, 2016, this issue). These contributions make it clear that attention needs to be drawn to the complex interactions involved. In this light, teacher noticing is a theoretical construct that challenges the reductionist assumptions that permitted parsing of teacher cognition and teacher performance.

However, attempts to account for an individual attending to specific issues and becoming aware of them have too often been oversimplified. They are usually based on the assumption that either the individual herself or himself determines what she or he will see, or else her or his environment determines it. We overcome this false dichotomy by using an information processing model that encompasses both top-down and bottom-up processes and that acknowledges the reciprocal and cyclical interaction between an individual and an environment.

The perceptual cycle model might be relevant to the current discussion on teacher noticing for several reasons, including: (1) the model accounts for, and distinguishes between, attentional orienting and active, extended attentional engagement with the environment; and (2) the interactive, reciprocal and cyclical characteristic of the perceptual cycle offers a promising tool to interpret the dynamic aspects involved in situation awareness.

In more detail, the perceptual cycle model distinguishes between an orienting response and the more extended processing necessary for subjective awareness. That is, transient shifts of attention can be relatively automatic, but sustained shifts often involve significant cognitive resources. The question naturally arises as to what determines whether a transient shift is followed by sustained allocation of attention. Neisser (1976) proposed that a person's own expectations of what belongs in a scene determine how sustained attention is directed, stating that: "Because we can see only what we know how to look for, it is these [anticipatory] schemata (together with the information actually available) that determine what will be perceived" (p. 20). Similarly, Sherin and Star (2011) specified that "what the teacher sees in the world is strongly driven by knowledge and expectations" (p. 73). In addition to an individual's knowledge and expectations, Schoenfeld (2011a) reminded us that "what you attend to […] is in large measure a function of your orientations" (p. 232). In this light, noticing takes place within the context of knowledge, beliefs, intentions, goals, expectations, and experiences, amongst others (in short, individual resources). However, these assertions do not suggest that individual resources and the environment

are uni-directionally related but instead bi-directionally related: Perceptual and conceptual processes involved in developing situation awareness are directed by the individual resources, and the outcome of perceptual exploration—the information picked up in the environment—modifies the original individual resources. Thus modified, they direct further exploration and determine what will be picked up in the environment next (see Neisser, 1976).

Dunekacke et al. (2016, this issue) argued that perception and interpretation provide the basis to activate teachers' knowledge and to make meaningful decisions. This assertion sounds reasonable; however, it is only half of the equation. Research on attentional capture and inattentional blindness (see Sect. 3) highlighted the importance of considering the potential impact of activated schemas for perceiving certain events. This issue has been addressed by Pankow et al. (2016, this issue) taking account of the relation between anticipation and identification of typical student errors. In short, in order to address issues of the interaction between cognition, perception, and environment both sides of the equation must be considered: the potential impact of individual resources on perception, and the potential impact of perceived information on individual resources, and their activation.

It is a central proposition of this paper that managing the perceptual and conceptual processes that permit situation awareness involve, and are shaped by, not only significant individual resources but also contextual resources. This position draws on Herbst et al.'s (2016, this issue) and Lande and Mesa's (2016, this issue) account for both individual and contextual resources in informing teachers' decision making. Individual characteristics such as knowledge, beliefs, goals, experiences, and intentions have been identified as having an impact for instructional actions (Borko, Roberts, & Shavelson, 2008; Schoenfeld, 2011b). Schoenfeld's (2011b) insightful investigations of in-the-moment decision-making posited that an individual's resources (including knowledge), orientations (including beliefs), and goals are critically important determinants in what teachers do, and why they do so. That is, according to Schoenfeld, one must know another person's resources, orientations, and goals well enough to predict what she or he will do in a given situation. However, Neisser (1976) reminded us that even then we cannot be sure what another person will do if we have an incomplete understanding of the situation in which the person is engaged. This is not in contradiction to Schoenfeld's (2011b) assertions but emphasizes the perspective that "perception and behavior are controlled interactively […] depend[ing] on the individual as well as the environment" (Neisser, 1976, p. 186). In this light, it is reasonable that Herbst et al. (2016, this issue) argued for going beyond the dominating account of individual cognitive factors by considering contextual resources as well. Attending to both the individual and the environment allows us to examine how the environment might affect the individual, and vice versa.

7 Concluding remarks

This paper draws on phenomena described in and findings gained from cognitive science and the applied science of human factors in the hope of finding a foundation for better understanding critical issues that have too often been overlooked in research on teacher noticing. The motivation for doing so was that although the notion of teacher noticing shows great promise for merging various research lines in mathematics education, we do not have access to the complexities involved in the processes involved, from attending to certain events, to becoming aware of these events in dynamic situations. Though turning to insights gained from cognitive science and the applied science of human factors might be beneficial to go beyond an intuitive model of teacher noticing (Sherin & Star, 2011), we need to be cautious about their ecological validity since they may not necessarily be approximations to what ordinarily takes place in classrooms and in classroom interactions.

At first glance, the accounts given in this paper seem to make the matter more mysterious: We cannot be sure that teachers 'see' certain events, though they direct their eyes to them. Even if they attend to certain events, we cannot be sure they become aware of them. And, even when they became aware of the events, we cannot be sure that the decisions they make are reasonable. This seems to be true as far as it goes; nevertheless, there are congruencies that the insights presented and briefly discussed in this paper point to. The bigger picture converges to the understanding that it is not only our eyes with which we see but also our minds. Our 'blindness' results not so much from our absence of attention but from our absence of expectation (or anticipation), knowledge, or beliefs. Even more importantly, the bigger picture converges to the understanding that it is all about the interdependencies between individual and environment, or, in more detail, the interactions between cognitive and contextual resources, perceptual and cognitive processes, and the actual situation. Thus, in this paper, teacher noticing—or more appropriately teacher situation awareness and teacher decision making—is treated as a construct that gives primacy to the interdependencies between teacher and environment.

Therefore, an important lesson to be learned from the inquiry thus far is that we need to step out of intuitive frames that hide the complexities involved in teacher noticing. With the above-mentioned arguments in mind, we may argue that both attending and developing situation awareness are mindful and cultural processes; however, attention

does not a priori lead to awareness. Attention selection results from the convolution of cognition and processing inputs from the environment, a convolution that takes place in a broader socio-cultural context. On the other hand, situation awareness requires recurrent interactions between an individual's cognitive and contextual resources, perceptual and conceptual processes, and the environment (including a broader, societal environment).

This more global orienting frame for discussions of teacher noticing allows us to rephrase the well-known slogan in research on teacher noticing "teacher noticing: seeing through teachers' eyes" to "teacher noticing: teachers' seeing with their minds' eyes" that takes place in continuous interdependence with the environment. Referring to the colloquial proverb by Richard Bach it can be formulated:

> Don't believe what your eyes are telling you. All they show is limitation. Looking with your understanding, find out what you already know, and you'll see the way to fly.

The same principle applies to this commentary: What is 'seen' in the assertions and arguments in this paper will depend not only on what was said in this paper but also on the reader's knowledge and beliefs prior to reading it.

Certainly, in any field as complex as teacher noticing is, it is difficult to develop deep theoretical understanding; however, we will not achieve this if we do not set our minds to it. The purpose of this paper was to do so by cultivating a theoretical perspective in research on teacher noticing by drawing on other research disciplines that may provide researchers and educators with useful insights into the complexities of an individual's attentional engagement with the environment and the development and maintenance of an awareness of the actual situation the individual is engaged in. The approach taken in this commentary was more than usually assertional in the hope of providing some degree of foresight in identifying important coming issues that need to be conceptualized in our field. The many advances provided in this special issue provide viable grounds for reconsidering how we might think more profoundly about the complexities in teacher noticing.

This paper directed to Sherin and Star's (2011) call for the development of a more comprehensive model of teacher noticing: "as a field, we should work toward the development of a more complete model of how teachers make sense, in the moment, of complex classroom events" (p. 77). A 'first cut' has been taken in accounting for the complex interactions involved in teacher noticing, drawing on Neisser's (1976) perceptual cycle model and blending sound insights from cognitive science and the applied science of human factors. It is hoped that the discussion presented here offers a promising theoretical perspective to further explore the complex interactions underlying the interdependencies involved in teacher noticing. In particular, more ground-breaking theoretical and empirical research is needed on the nature and dynamics of the resources and processes involved in understanding teacher situation awareness and decision-making in real-time events. It is hoped that the discussion reinforces the intellectual framing of what we need to set our minds to in the future in order to enlighten the black box of teacher noticing.

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